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ESTIMATING TOTAL GAS CONTENT FROM EARLY STAGE GAS EMISSION DATA

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ABSTRACT

The measurement of gas content plays an important role in mine safety and resource evaluation for coal and coalbed methane gas recovery. Gas content analysis data was gathered from eight Australian coal mines, representing the three major coal producing regions of the north-west and southern Sydney Basin and the Bowen Basin. The combined dataset, comprising more than 4 700 samples, is considered representative of the variable conditions that may be encountered in Australian coal mines, which among other properties include variable gas content, gas composition, permeability, rank, type and structure.

Analysis of the data has identified significant and consistent relationships between the three gas content components, Q_1, Q_2 and Q_3, as determined through fast desorption gas content testing. These relationships and the impact of gas composition are discussed. Several new methods to estimate total gas content are also presented. These methods, based on initial gas emission data, enable values of average and maximum likely total gas content to be provided to operators and planners upon completion of the initial field desorption testing, following core recovery, prior to the coal sample being dispatched to the gas analysis laboratory. The rapid availability of such data is particularly useful when required for operational decision making such as in mines with coal and gas outburst risk.

INTRODUCTION

Coal mines operating in seams with moderate to high gas content employ routine gas drainage drilling ahead of mining to reduce gas content for two purposes; compliance with prescribed outburst threshold limits, and compliance with prescribed mine ventilation air (MVA) gas concentrations limits. Core samples are regularly collected during exploration and gas drainage drilling and tested in accordance with the fast desorption method, described in AS3980 (1999), to determine the content and composition of the seam gas. Gas analysis is an integral part of the mine's ability to effectively manage the ventilation, gas and outburst risk. Fast desorption gas content analysis typically produces results within 24 hours.

Figure 1 shows a typical underground-to-inseam (UIS) gas drainage drilling pattern employed at gassy Australian underground coal mines. Where gas content testing confirms an area remains above the prescribed limit additional boreholes are drilled in an attempt to rapidly reduce the gas content and avoid mine production delays.

[1] *Pacific Mining and Gas Management (PacificMGM),* www.pacificmgm.com.au

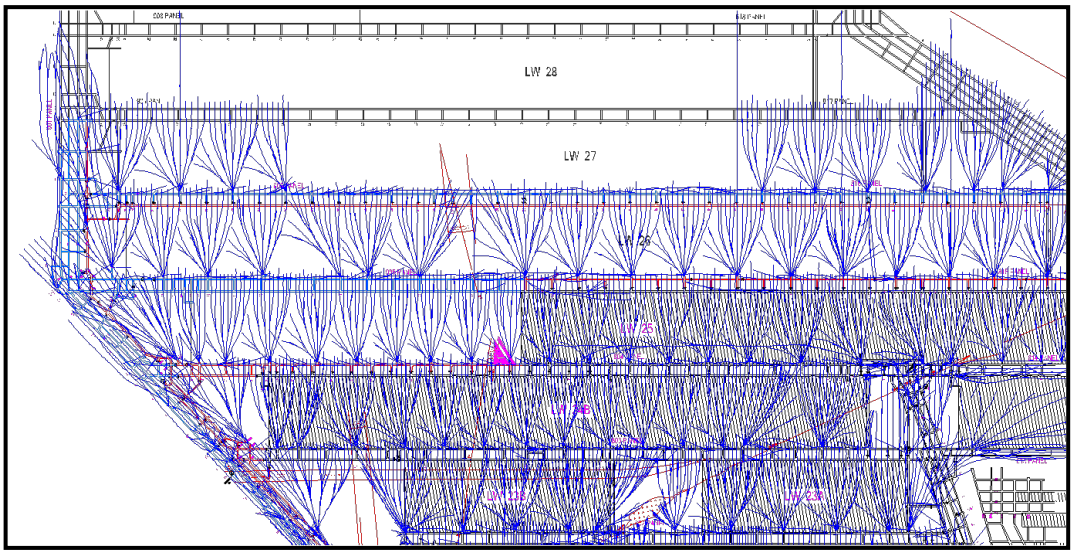

Figure 1 – Typical underground-to-inseam (UIS) gas drainage in gassy Australian UG mines

DATA ACQUISITION AND ANALYSIS

The results of core sample gas testing were gathered from eight Australian coal mines representing the major coal producing basins of both Queensland and New South Wales. As shown in Table 1, gas test data was collected from 4 785 coal samples. In preparing the dataset for analysis 600 test results were excluded, 598 due to the combined CH_4 and CO_2 gas concentration being less than 60%, suggesting leakage and possible data error, and two (2) due to the desorption rate index (DRI) value exceeding 3 500. A total of 4 185 gas test results were analysed.

Table 1 – Summary of underground –to-inseam (UIS) core sample data source

Mine Reference	State	Gas Composition	Total Samples	Samples Analysed
Mine A	NSW	Mixed CH_4 - CO_2	527	517
Mine B	NSW	Mixed CO_2 - CH_4	414	311
Mine C	NSW	Mixed CO_2 - CH_4	770	770
Mine D	QLD	CH_4	1 047	1 029
Mine E	NSW	CO_2	441	0
Mine F	QLD	CH_4	383	379
Mine G	QLD	CH_4	393	376
Mine H	QLD	CH_4	810	803
TOTAL SAMPLES			4 785	**4 185**

Analysis of seam gas composition confirmed CH_4 as the dominant seam gas in Australian underground mines. CO_2 was found to be concentrated in areas of the Bulli seam in the southern Sydney Basin with mixed gas composition occurring in the transition zones between CH_4 and CO_2 rich areas.

Analysis of Gas Content Components

The total gas content of coal samples is composed of three separate gas content measurements as shown in Equation 1 (AS3980, 1999).

$$Q_T = Q_1 + Q_2 + Q_3 \quad (1)$$

Where: Q_T = total gas content (m^3/t)
Q_1 = lost gas component (m^3/t)
Q_2 = desorbed gas component (m^3/t)
Q_3 = crushed gas component (m^3/t)

The Q_1 component represents the gas lost from a coal sample, subsequent to being removed from its *in situ* position, prior to being sealed in a gas desorption canister. The Q_2 component represents the gas desorbed from a non-pulverised coal sample during laboratory gas emission testing at atmospheric pressure. The Q_3 component represents the gas liberated from a coal sample at atmospheric pressure, measured following crushing. The duration of desorption testing, prior to crushing has a significant impact on the relative amount of gas emission measured during Q_2 and Q_3 testing. AS3980 (1999) states Q_2 testing may be deemed complete when the rate of gas evolution approaches an asymptotic value.

Figure 2 shows the values of each gas content component relative to the total gas content reported from each coal sample. The average Q_1 gas content was 0.4 m^3/t, ranging from a low of 0.0 m^3/t to a high of 4.3 m^3/t. The average Q_2 gas content was 1.2 m^3/t, ranging from a low of 0.0 m^3/t to a high of 11.7 m^3/t. The average Q_3 gas content was 4.5 m^3/t, ranging from a low of 0.3 m^3/t to a high of 12.7 m^3/t. The value of each gas content component was found to increase in response to increasing total gas content.

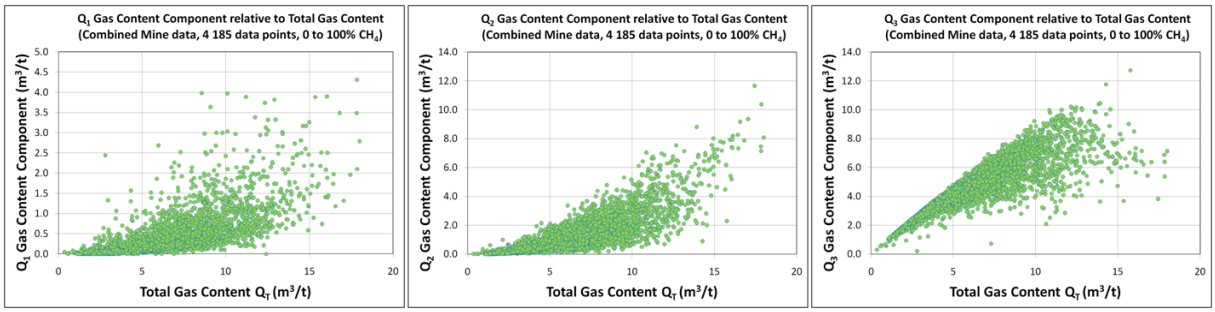

Figure 2 – Gas content component volume relative to total gas content

Figure 3 shows the average value of each gas content component calculated from samples grouped according to total gas content and gas composition. As indicated in Figure 3 the value of each component increases in response to increasing total gas content, however there is little change across the gas composition range. The results suggest gas composition has little impact on the rate of gas emission during fast desorption gas content testing.

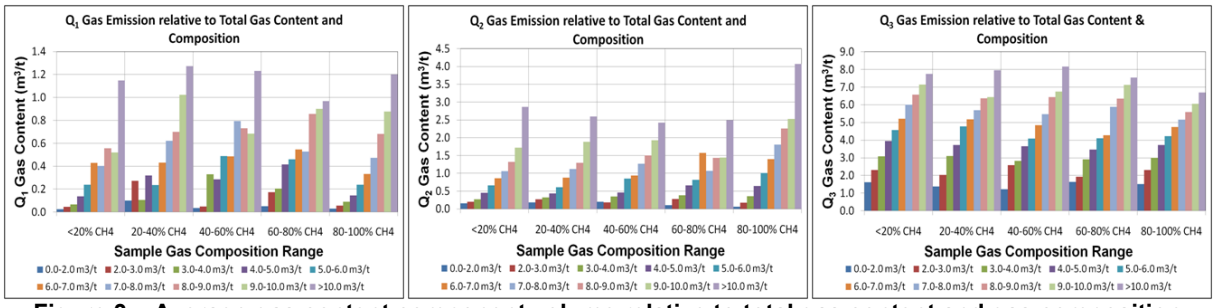

Figure 3 – Average gas content component volume relative to total gas content and gas composition

Figure 4 shows the average ratio of each gas content component relative to the total gas content calculated from samples grouped according to total gas content and gas composition. From the data it can be seen that Q_1:Q_T and Q_2:Q_T ratio increase while the Q_3:Q_T ratio decreases in response to increasing Q_T. The results indicate that where Q_T is low the bulk of the freely liberated gas has been lost, leaving predominantly the retained Q_3 component, and as Q_T increases so too does the volume of gas able to be freely liberated during Q_1 and Q_2 desorption which thereby reduces the Q_3 component percentage.

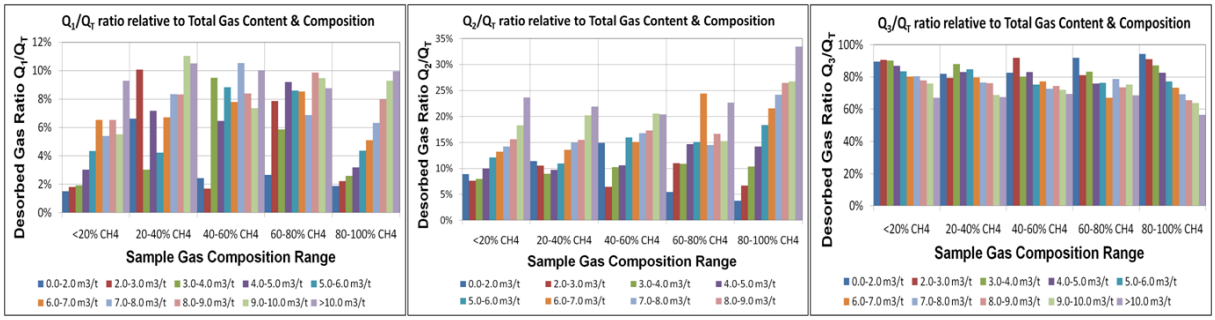

Figure 4 – Average $Q_{(1,2,3)}$:Q_T ratio relative to total gas content and gas composition

Relationship between Gas Content Components – Q_1, Q_2 and Q_3

The relationship between each of the gas content components was also considered. Figure 5 and Figure 6 show gas content component values plotted relative to total gas content inclusive of linear and power formula relationships respectively representing the average of each gas content component.

For Q_T greater than 7.0 m^3/t, an increase in the scatter of both Q_2 and Q_3 was evident therefore the data was separated to consider the average linear relationship above and below this transition value.

For Q_T less than 7.0 m^3/t the linear average of each gas content component, relative to Q_T, was represented by the following equations.

$$Q_1 = 0.0441 \times Q_T$$
$$Q_2 = 0.1561 \times Q_T$$
$$Q_3 = 0.7998 \times Q_T$$

For Q_T between 7.0 and 14.0 m^3/t the linear average of each gas content component, relative to Q_T, was represented by the following equations.

$$Q_1 = 0.1565 \times Q_T - 0.6968$$
$$Q_2 = 0.4531 \times Q_T - 1.9808$$
$$Q_3 = 0.3925 \times Q_T + 2.6540$$

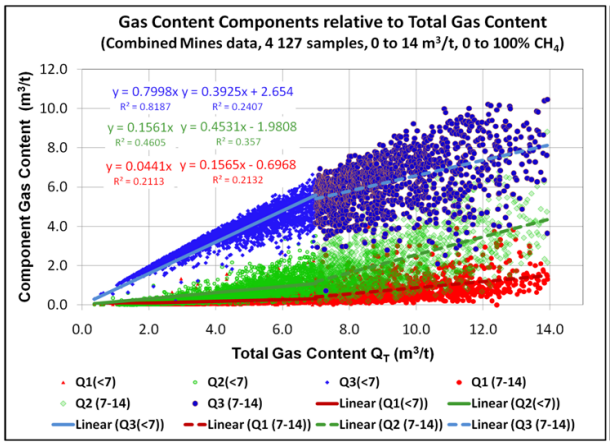

Figure 5 – Gas content component values plotted relative to total gas content including linear trendlines representing the average of each component within Q_T range 0-7 m^3/t and 7-14 m^3/t

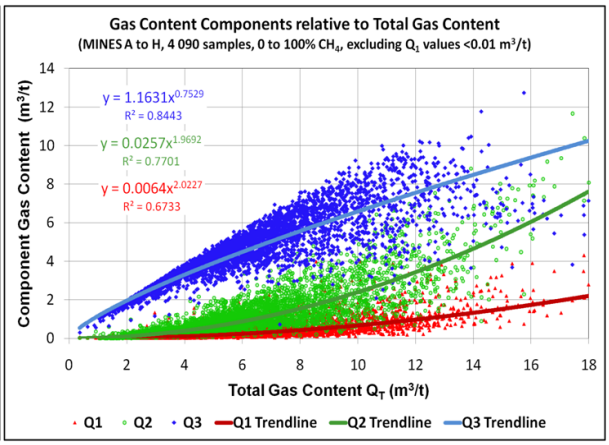

Figure 6 – Gas content component values plotted relative to total gas content including trendlines showing the power relationship representing the average of each component

Given the trend of increasing Q_1 and Q_2 and decreasing Q_3 relative to increasing Q_T a power relationship was considered as a means for accurately representing the average of each gas content component relative to the total gas content. As shown in Figure 6, each gas content component was represented by the following equations and in each case the correlation was stronger that achieved using a linear relationship.

$$Q_1 = 0.0064.Q_T^{2.0227}$$
$$Q_2 = 0.0257.Q_T^{1.9692}$$
$$Q_3 = 1.1631.Q_T^{0.7529}$$

Given the comparatively strong correlation a power relationship was considering to most accurately represent the relationship between total gas content and each of the three gas content components within the total dataset.

Figure 7 and Figure 8 show the impact of gas composition on the average of each gas content component relative to total gas content when represented by linear and power formulae respectively. The Q_1 component was found to be independent of gas composition. Also, for total gas content less than 7.0 m^3/t gas composition was found to have little impact on gas emission behaviour. As total gas content increased above 7.0 m^3/t it was found that the Q_2:Q_T ratio increased while the Q_3:Q_T ratio decreased. The effect was more significant in CH_4 rich coal samples suggesting that, at increased total gas content, CH_4 liberated from coal samples at a greater rate than CO_2.

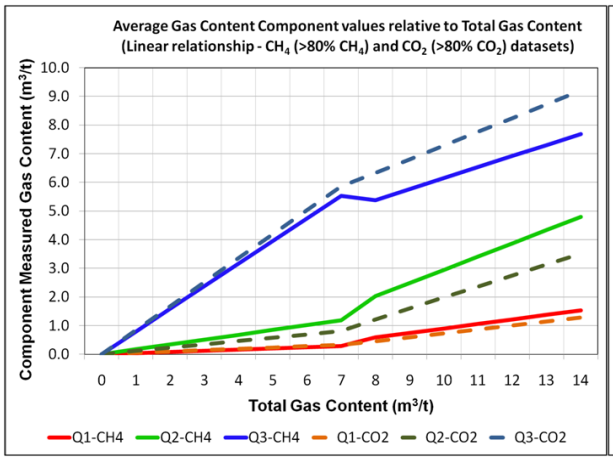

Figure 7 – Impact of gas composition on average gas content component values relative to total gas content, based on linear average relationship

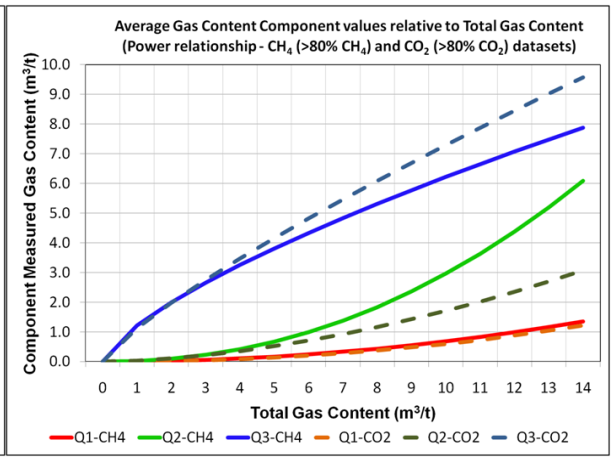

Figure 8 – Impact of gas composition on average gas content component values relative to total gas content, based on average power formula relationship

Estimating Average Total Gas Content from Q_1 Lost Gas Content

Given the strong relationship between Q_1 and Q_T, it was proposed that average total gas content for a coal sample may be estimated using the Q1 gas content value, once determined in the field.

The Q_1 gas content was shown to be independent of gas composition and the average Q_T-Q_1 relationship was best represented by a power formula, shown in Equation 2, where α and β are variables.

$$Q_{T(ave)} = \alpha \times Q_1^{\beta} \qquad (2)$$

Figure 9 shows the results of total gas content plotted relative to the Q_1 gas content component for the complete dataset. The variables α and β that represent the average total gas content relative to the Q_1 gas content component are 9.3729 and 0.3328 respectively.

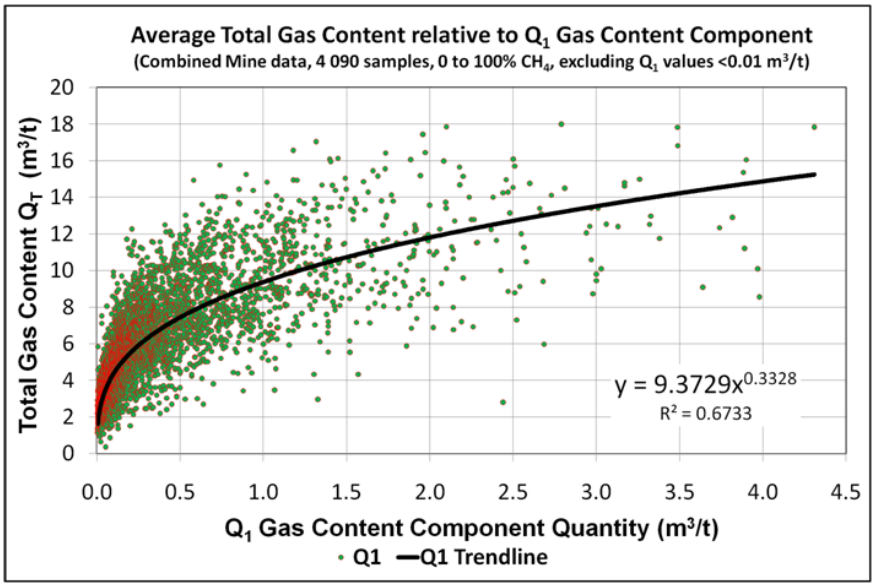

Figure 9 – Q_T-Q_1 data for the complete dataset, including trendline representing average total gas content relative to the Q_1 gas content component

Initial Gas Desorption Rate

The initial gas desorption rate (IDR) was investigated to determine the relationship to total gas content and the impact of gas composition. A separate measure of the rate of gas emission during the early stage of gas desorption from a coal core samples is known as IDR30. The IDR30 is a measurement of the quantity of gas desorbed per unit mass from a coal sample during the first 30 minutes of crushing (Williams, 2002). Analysis of the gas desorption data confirmed a strong correlation (R^2 = 99%) between IDR and IDR30, with the relationship represented by Equation 3.

$$IDR\ (ml/min^{0.5}/kg) = 167 \times IDR30\ (m^3/t) \tag{3}$$

The impact of gas content and composition on both IDR and IDR30 was investigated. The data suggest initial desorption rate was closely related to total gas content with the relationship being independent of gas composition.

Figure 10 show IDR values plotted relative to the total gas content for each sample. As reported by Williams (2002), samples having an abnormally high IDR and low Q_T may be the result of leakage from the desorption canister while in transit between the mine and the gas analysis laboratory. However a highly fractured core can also produce an abnormally high IDR value relative to Q_T.

Considering the data presented, a clear upper limit was evident, defining a maximum total gas content envelope corresponding to a given IDR.

Estimating Maximum Total Gas Content from Initial Gas Desorption Rate

From the assessment of the relationship between Q_T and IDR it was proposed that the maximum total gas content of a coal sample may be estimated using the result of initial gas desorption rate measurement, once determined in the field. The maximum gas content envelope was represented by Equation 4.

$$Q_{T(max)} = 2.5665 \times \ln(IDR) + 2.1686 \tag{4}$$

Estimating Average Total Gas Content from Initial Gas Desorption Rate

Figure 11 shows total gas content plotted relative to the square root of initial desorption rate. Presenting the Q_T – IDR data from the combined mine dataset in this manner was found, through statistical analysis, to have a correlation of 0.656.

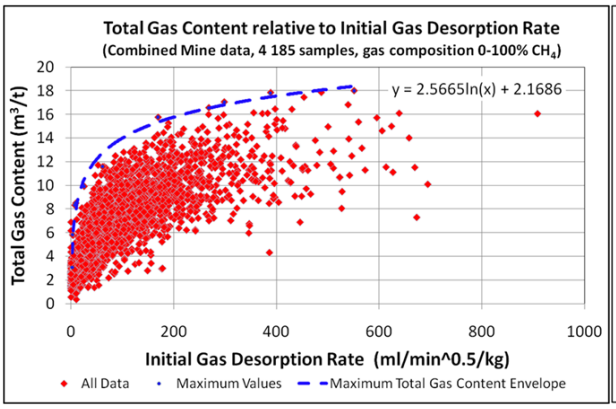

Figure 10 – Total gas content relative to initial desorption rate, including maximum total gas content envelope

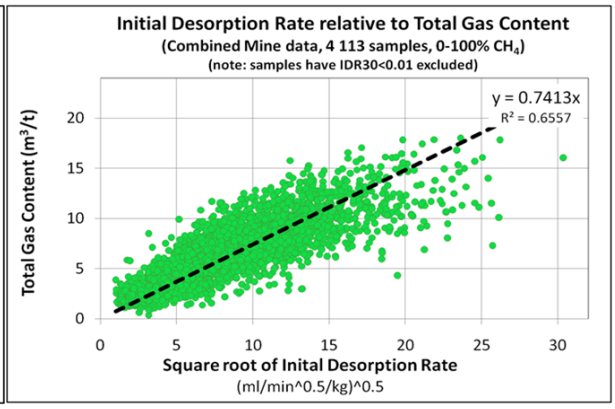

Figure 11 – Total gas content relative to square root of initial desorption rate

The analysis was extended to consider the impact of gas composition which confirmed the relationship to be virtually independent of gas composition. From this assessment it was proposed that initial gas desorption rate may also be used to estimate the average total gas content using Equation 5.

$$Q_{T(ave)} = 0.7413 \times \sqrt{(IDR)} \tag{5}$$

CONCLUSIONS

A dataset comprising more than 4 000 core samples, testing using the fast desorption method for gas content testing, representing mines from Australia's major coal producing regions, was prepared and analyzed. The analysis identified consistent gas emission behavior during early stage desorption, which was independent of gas composition, particularly in samples having a total gas content less than 7.0 m^3/t.

The strong relationships between total gas content and each of Q_1 lost gas content and initial desorption rate led to equations being proposed, for use by mine operators, to estimate both average and maximum likely total gas content.

Although only an estimate, an indication of average and maximum total gas content can be of significant benefit to mine operators, particularly in outburst prone conditions, enabling appropriate response actions can be planned in advance, prior to receiving the result of gas analysis testing from the laboratory

REFERENCES

AS3980 (1999) Guide to the determination of gas content of coal – direct desorption method, Standards Association of Australia AS3980-1999.

Williams, R.J. (2002) Gas content testing for outburst management compliance, *Proceedings of the 3rd Australasian Coal Operator's Conference COAL2002*. Australasian Institute of Mining and Metallurgy. Wollongong. 6-8 February 2002. pp.47-52.